Search for Resonances in $\gamma p \to \omega \eta p$ at GlueX

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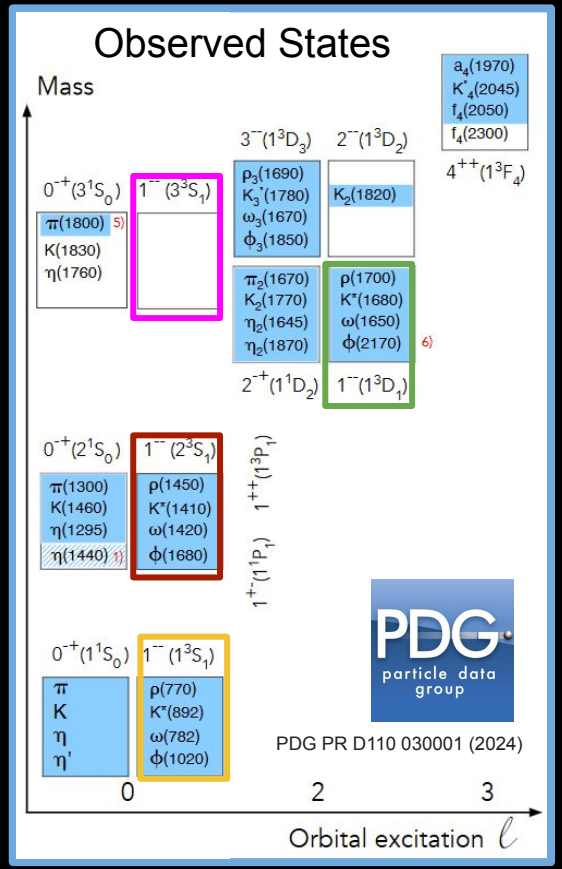
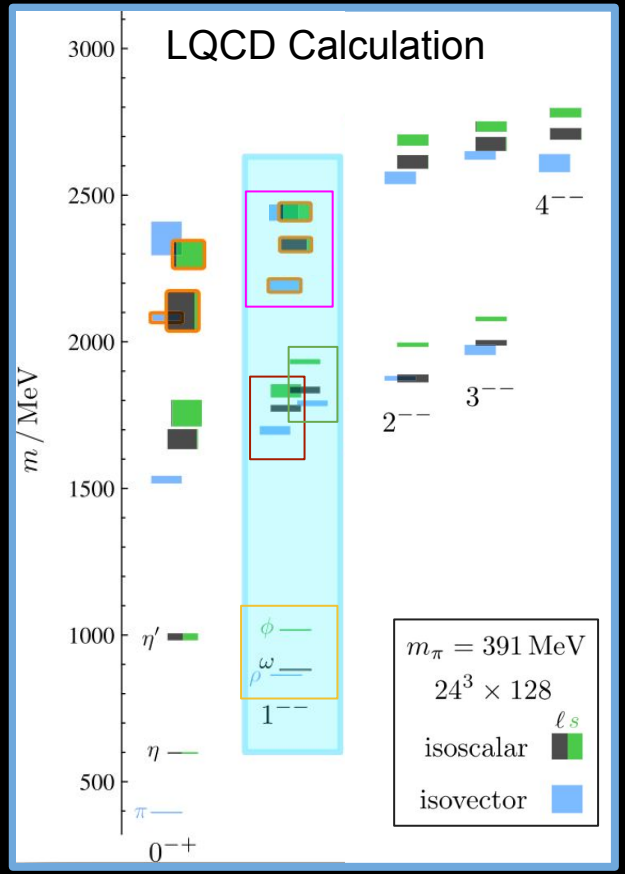
On behalf of the GlueX Collaboration

Vector Meson Spectrum

J. Dudek et al. PR D88 094505 (2013)

- SU(3) flavor multiplets grouped in nonets
- Unrealistic pion masses outputs unreliable masses
- Understanding of QCD dynamics
- Understand the over and under population in groups





Possible Isoscalar Resonances Decaying to $\omega\eta$

l	J^{PC}		
0 (S)		1^{+-}	
1 (P)	0^{--}	1^{--}	2^{--}
2 (D)	1^{+-}	2^{+-}	3^{+-}
3 (F)	2^{--}	3^{--}	4^{--}

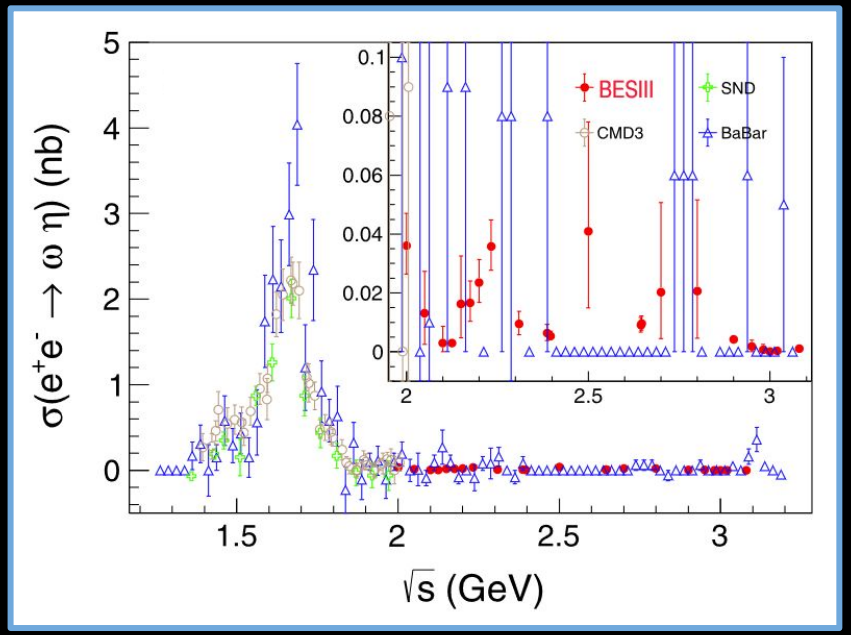
- Isoscalar resonances:
  - Need more evidence to properly establish them
  - Expected but never seen
  - Exotic mesons
  - Established but not seen in $\omega\eta$

Summary of Previous Experiments

Experiment	Beam	Statistics
Omega Photon	$\gamma p \rightarrow \omega\eta p$	~100 $\omega\eta$
BESIII	$e^+e^- \rightarrow \omega\eta$	~200 $\omega\eta$
CMD3	$e^+e^- \rightarrow \omega\eta$	~800 $\omega\eta$
SND	$e^+e^- \rightarrow \omega\eta$	~900 $\omega\eta$
BaBar	$e^+e^- \rightarrow \omega\eta$	~1.4k $\omega\eta$
E852	$\pi^- p \rightarrow \omega\eta n$	~20k $\omega\eta$

- e^+e^- reactions only produce 1^{--} states

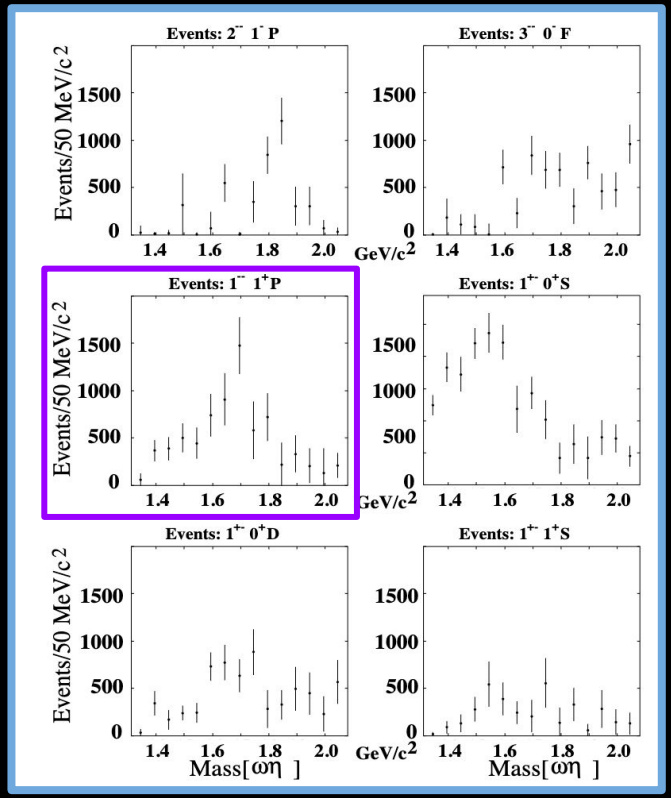
BESIII Phys. Lett. B 813:136059 (2021)



The Power of Partial Wave Analysis (PWA)

- PWA decomposes the intensity into waves corresponding to their angular momentum
- Individual amplitude contributions are extracted
  - Overlapping estates can be separated
  - New enhancements on distributions can be revealed
- Identification of resonances' J^{PC}

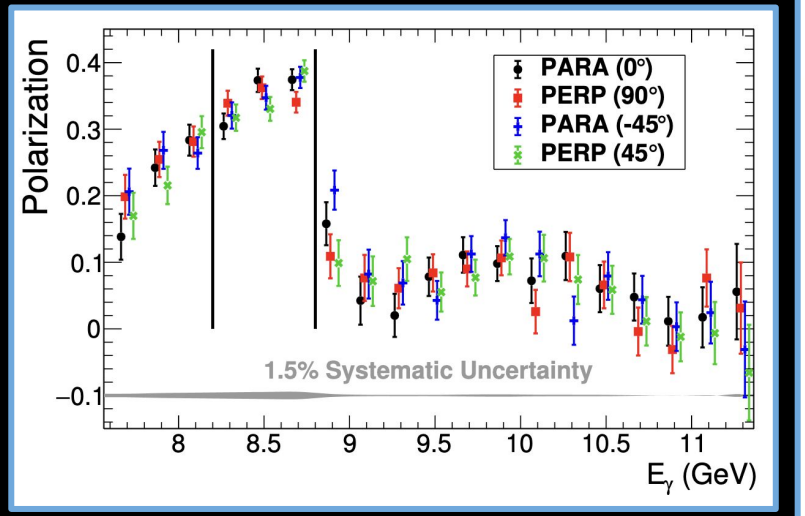
E852 PWA $\pi p \rightarrow \omega\eta$



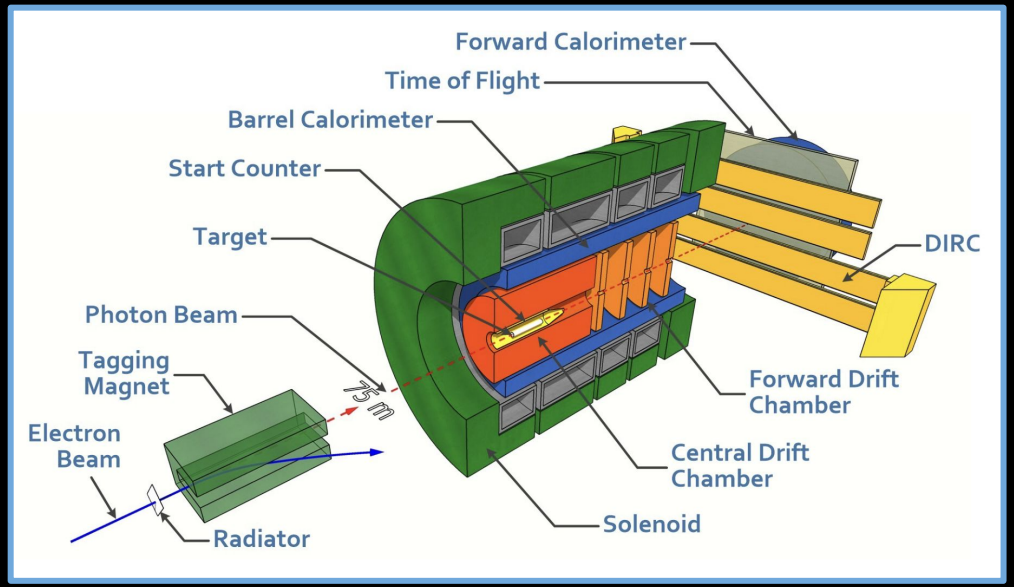
BNL-E852 PL B397 190 (2001)

GlueX Experiment

- Linearly polarized photon beam
- Almost complete angular coverage
- GlueX-I completed
- GlueX-II ~35%

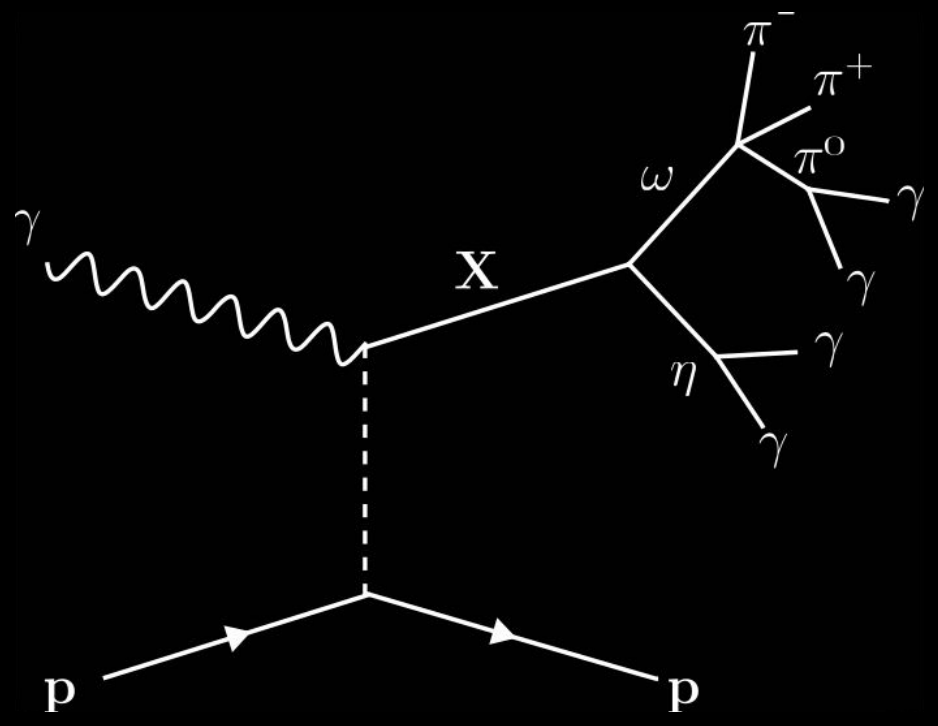


Nucl. Instrum. & Meth. A**987**, 164807 (2021)



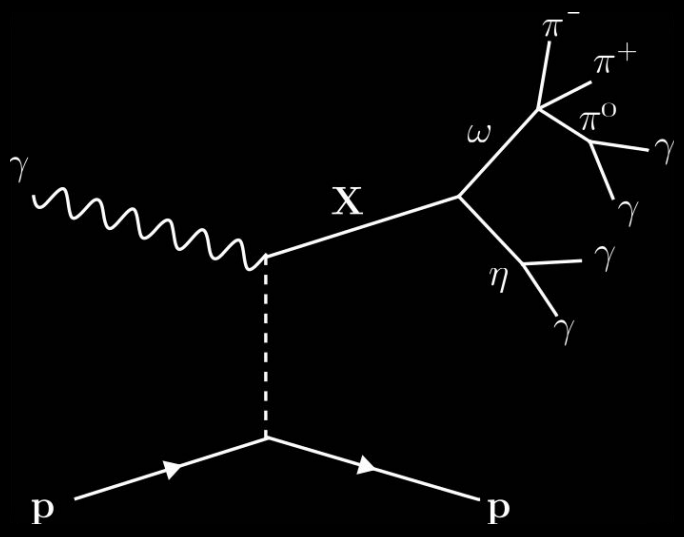
Data Selection

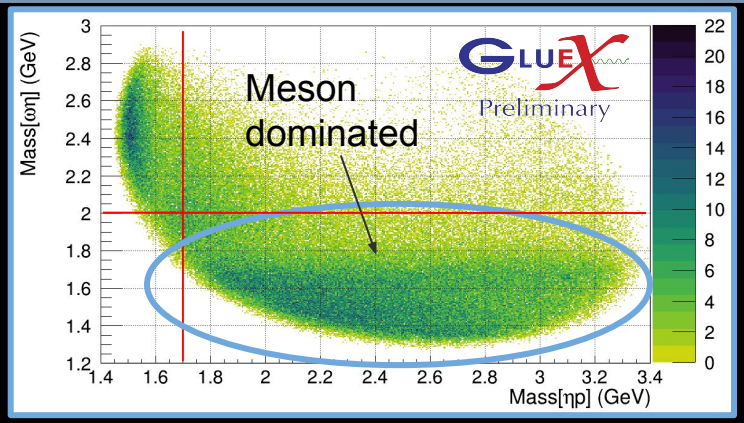
- All particles are reconstructed and pass through a Kinematic Fit
- Type of data selection
  - Select best particle hypothesis
  - Fiducial cuts
  - Cut on beam energy and momentum transfer
  - Sideband subtraction
- Data sample: GlueX-I

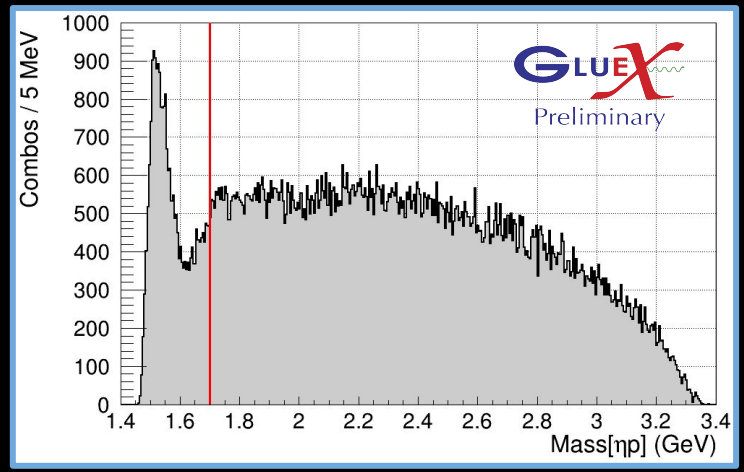


Different Physics in $\omega\eta p$

- PWA of the meson system
- Direct measurement of N(1535) width in M[ηp]







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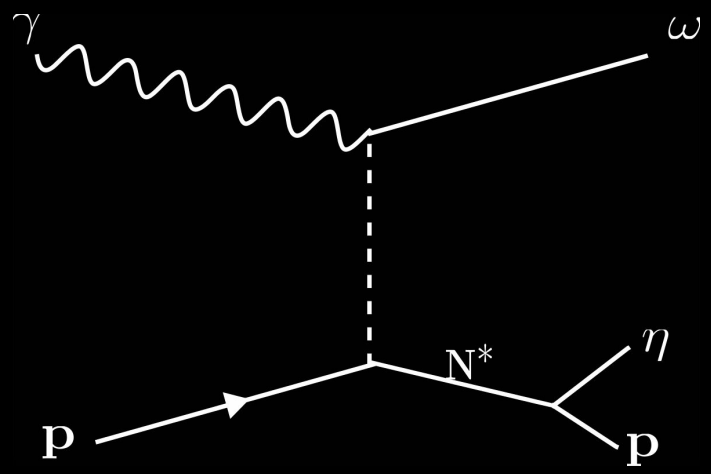
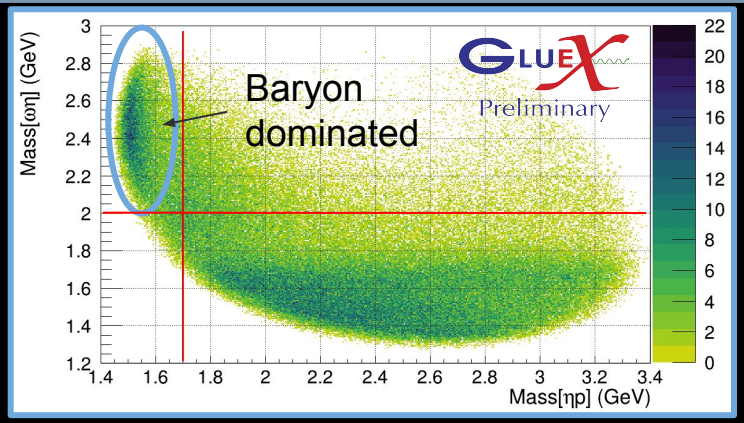
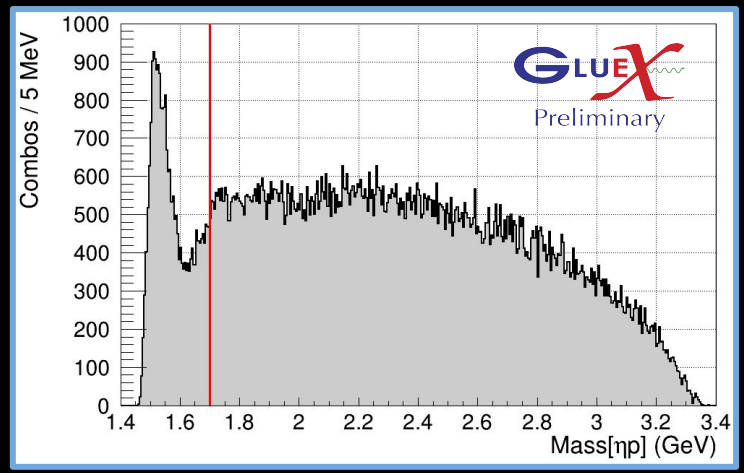






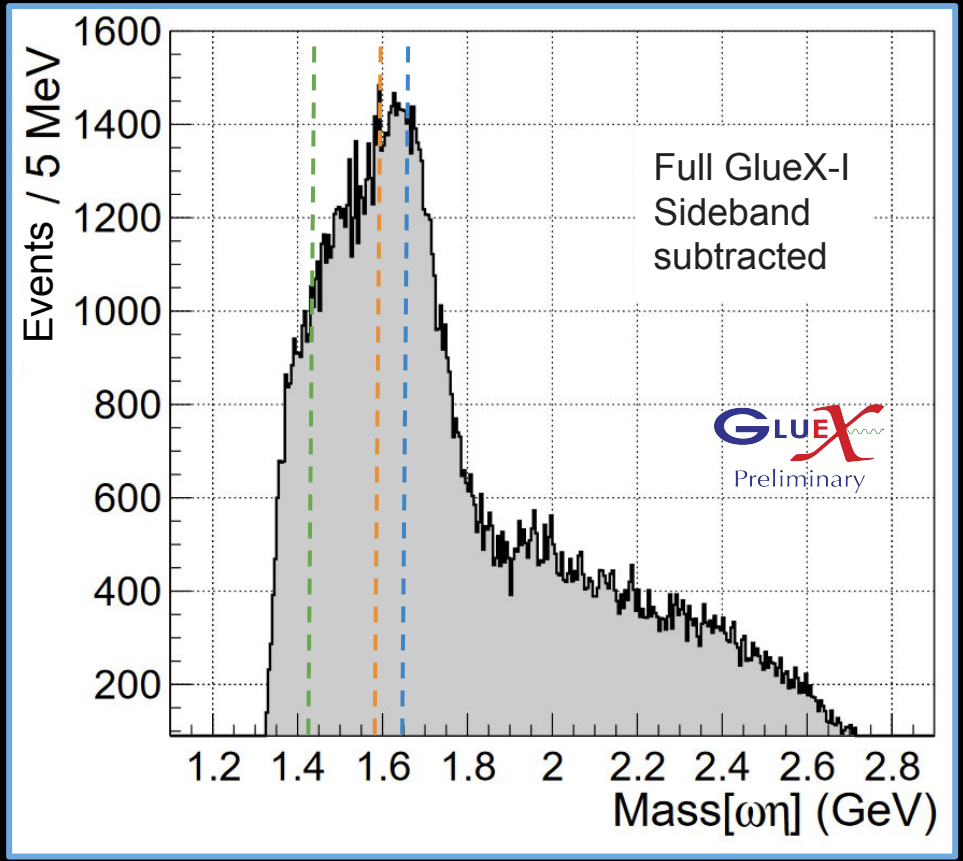
Results for $\omega\eta$ Selection

- The integral of M[$\omega\eta$] with sideband subtraction is ~143k
- Expected states and their PDG estimate:

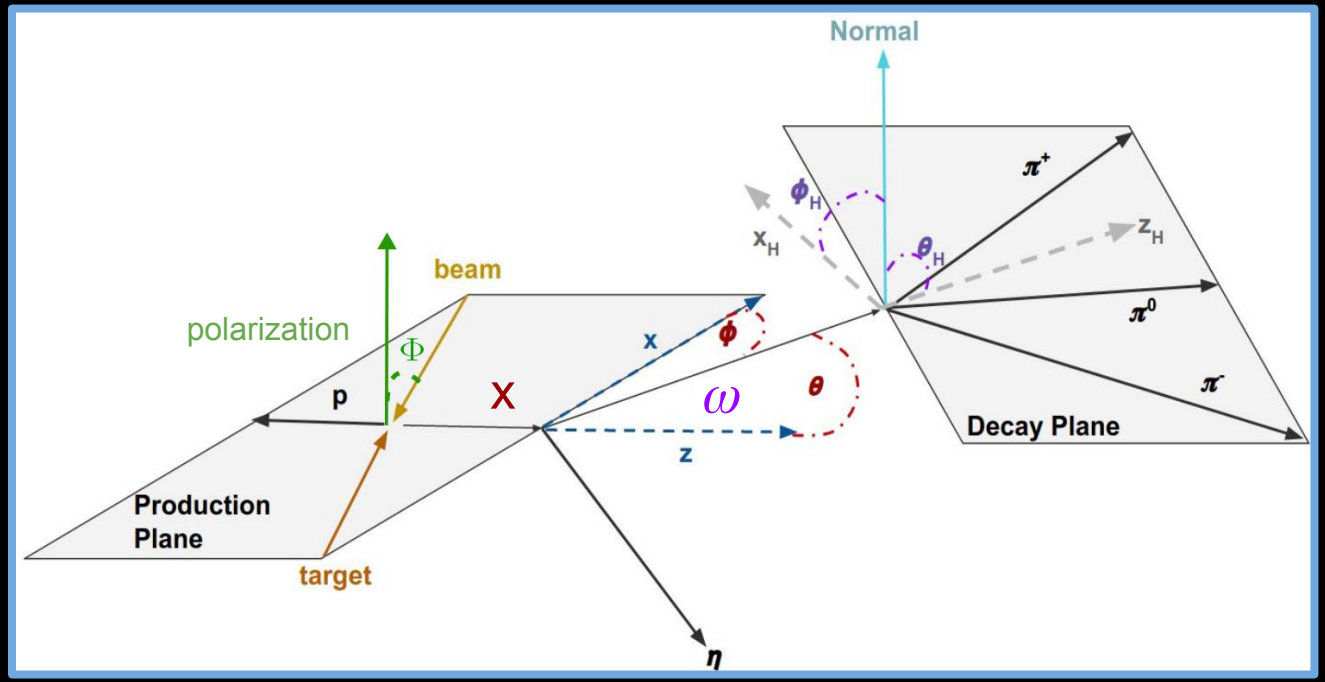
  -ω(1420) width: 290 MeV

  -h_1(1595) width: 385 MeV

  -ω(1650) width: 315 MeV



Intensity for Vector-Pseudoscalar PWA



- The intensity $I(\Phi, \Omega, \Omega_H)$ depends on the angles that describe the decay of X system and ω

Intensity for Vector-Pseudoscalar PWA

$$I(\Phi,\Omega,\Omega_H) \approx (1-P_\gamma)\left[\left|\sum_{J_\ell,m}[J_\ell]_m^{(-)}\mathrm{Im}(Z_{J_\ell}^m)\right|^2+\left|\sum_{J_\ell,m}[J_\ell]_m^{(+)}\mathrm{Re}(Z_{J_\ell}^m)\right|^2\right]$$
$$+(1+P_\gamma)\left[\left|\sum_{J_\ell,m}[J_\ell]_m^{(+)}\mathrm{Im}(Z_{J_\ell}^m)\right|^2+\left|\sum_{J_\ell,m}[J_\ell]_m^{(-)}\mathrm{Re}(Z_{J_\ell}^m)\right|^2\right]$$

$$Z_\ell^m(\Phi,\boxed{\Omega},\Omega_H) = e^{-i\Phi}X_\ell^m(\Omega,\boxed{\Omega_H})$$

Decay to vector-pseudoscalar

Decay of vector

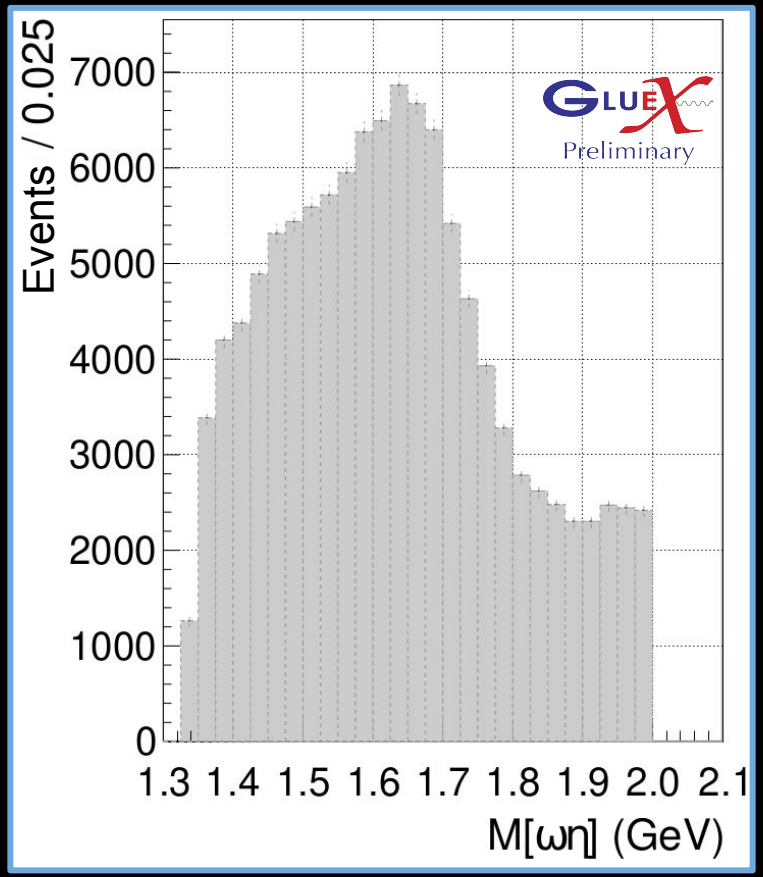
- natural (unnatural) parity exchange

PWA: Mass Independent Fit to GlueX-I

- Simple model with the expected dominant waveset
  - P wave:

    1^{--} (m= -1, 0, +1), $\varepsilon \mp$
  - S wave:

    1^{+-} (m= -1, 0, +1), $\varepsilon \mp$
- Strong contribution from P and S waves
- Studies including 2^{--} and the exotics 0^{--} & 2^{+-} are in progress



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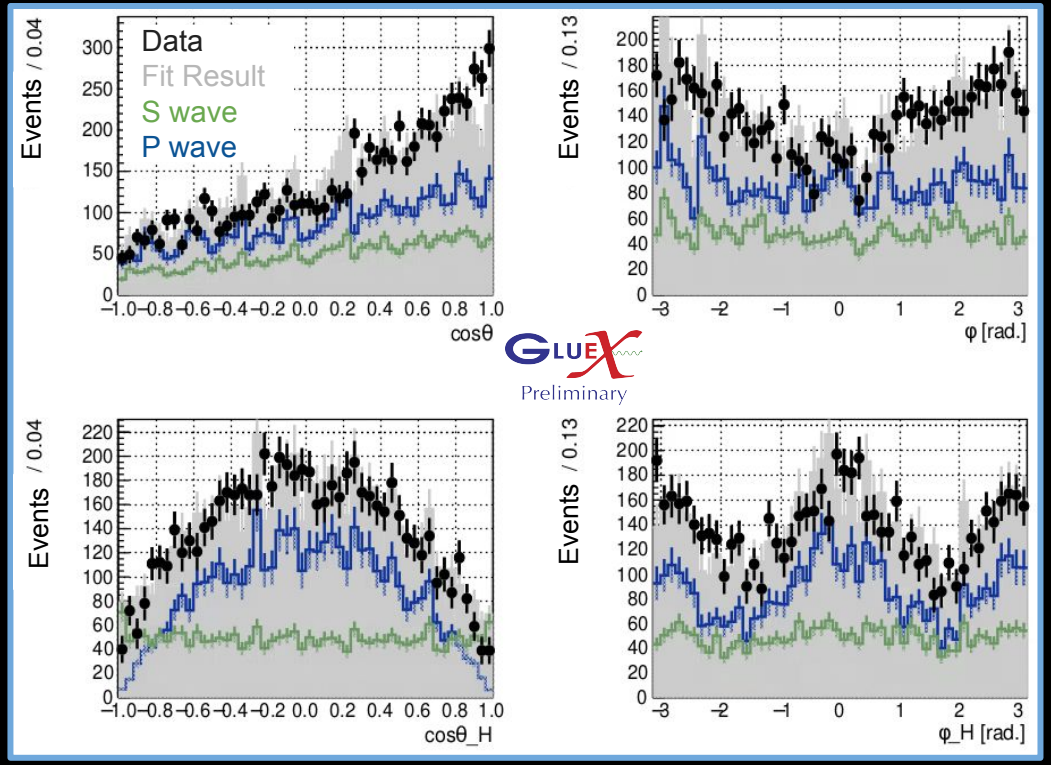
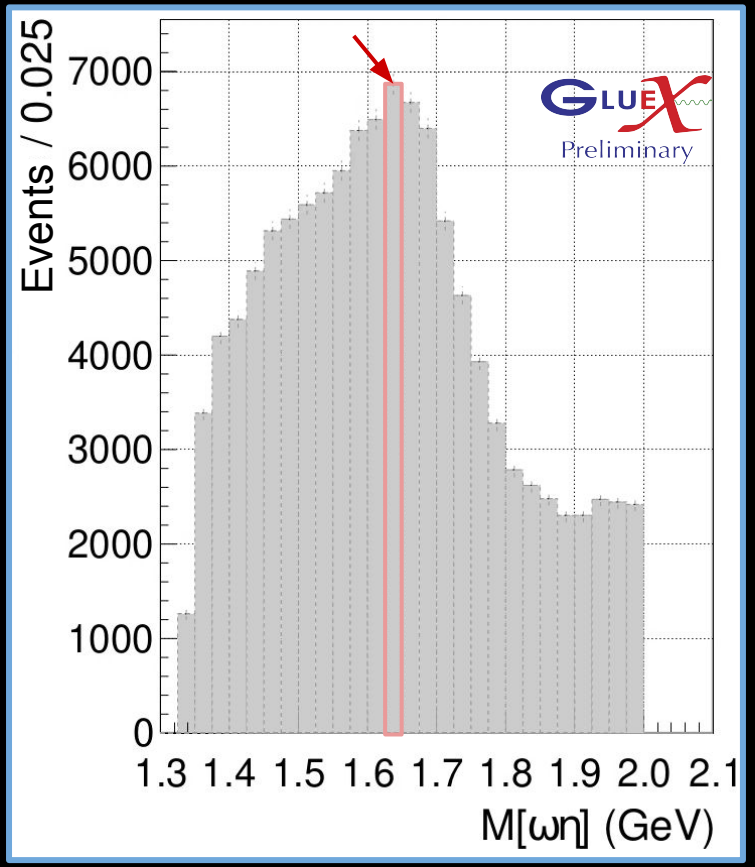
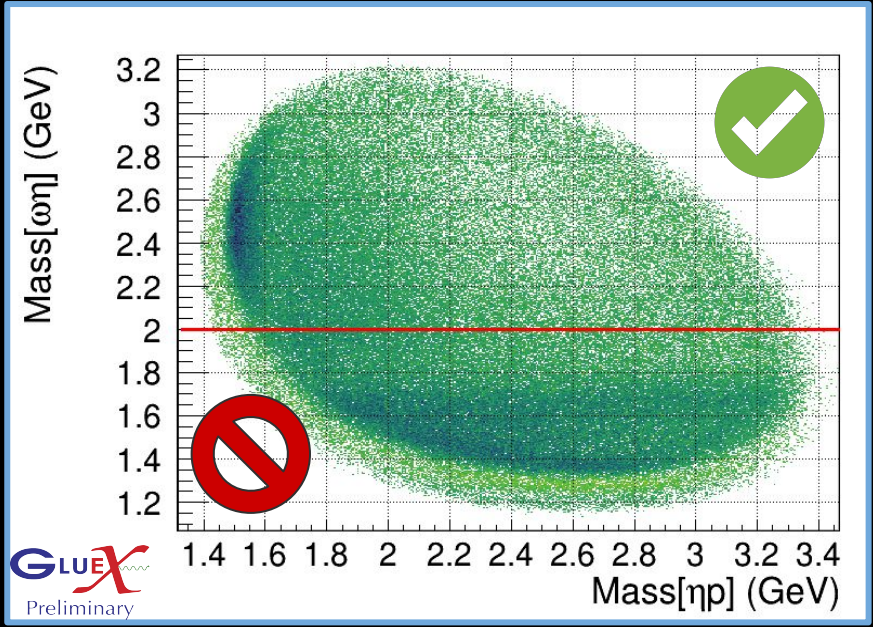
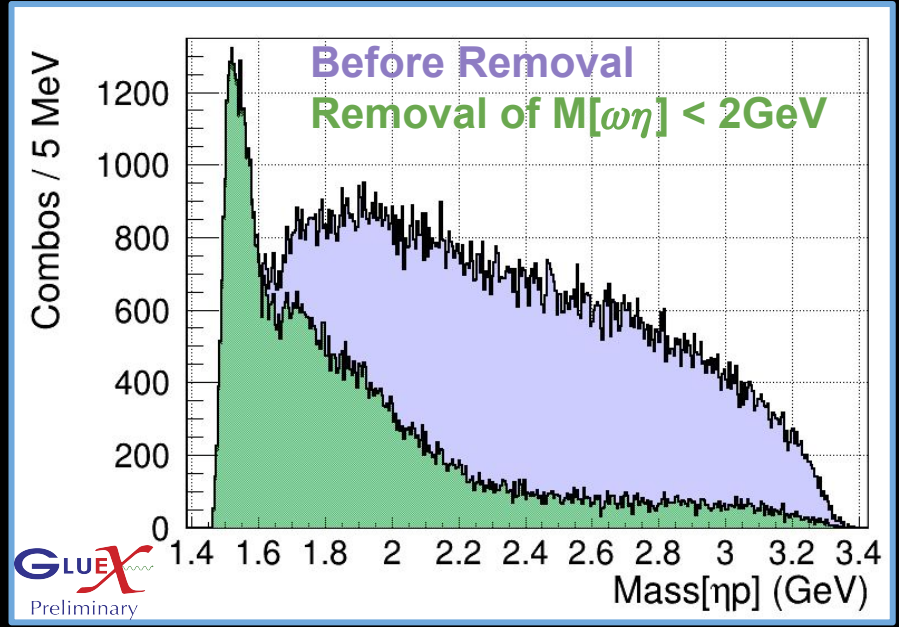




N* Physics: Meson System Veto

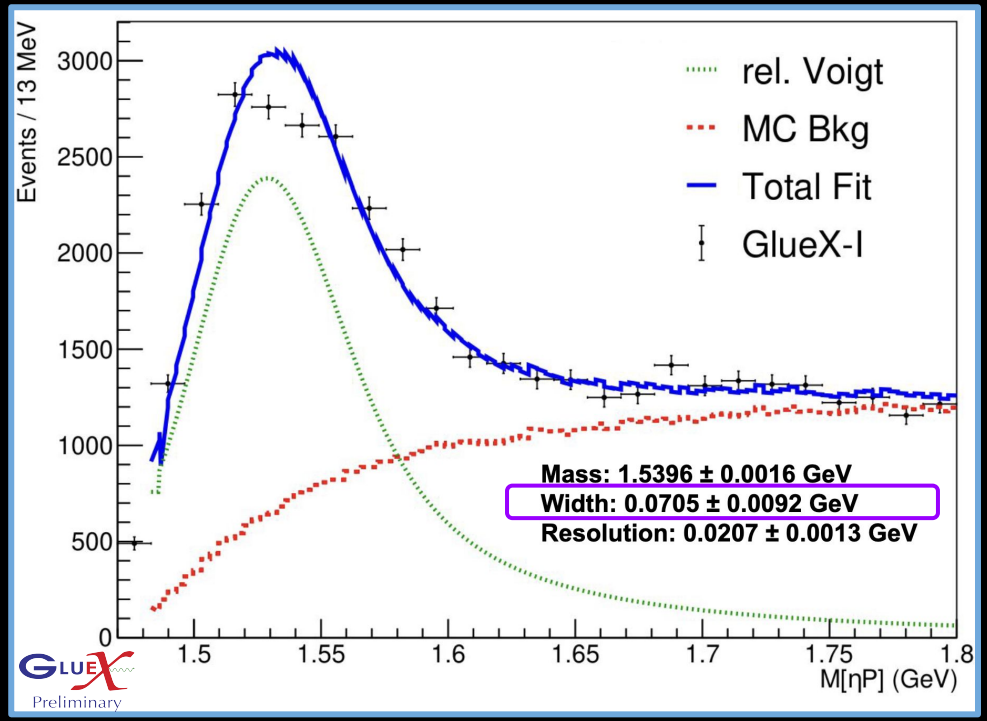




- Modified the selection to enhance N* events
- The meson-dominant and the N* system are separated

Direct Estimation of the Width

- The PDG estimates the N(1535) Breit-Wigner width between 125 - 170 MeV
- Preliminary study suggests a narrower width
- Model: relativistic Voigt + MC $\omega\eta$ phasespace shape (bkg)



Summary

- The M[$\omega\eta$] distribution has ~143k events for GlueX-I, which is at least 7 times bigger than previous experiments
- Simple PWA model shows contribution from the S(1^{+-}) and P(1^{--}) waves where ω(1420), h_1(1595), and ω(1650) are expected
- Future PWA models might include the waves 0^{--}, 2^{--}, 2^{+-}, etc…
  Exotic Never seen
- Preliminary fits suggest a width half of the PDG value for the N(1535)

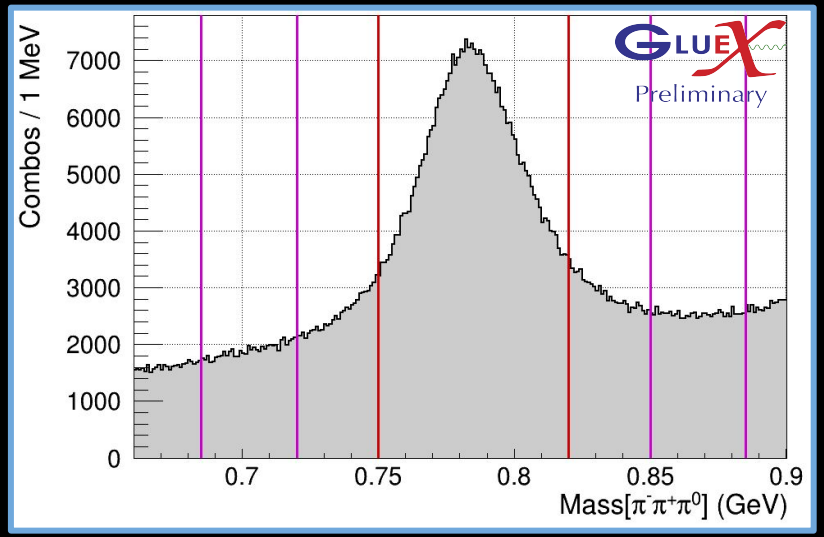
GlueX acknowledges the support of several funding agencies and computing facilities: gluex.org/thanks

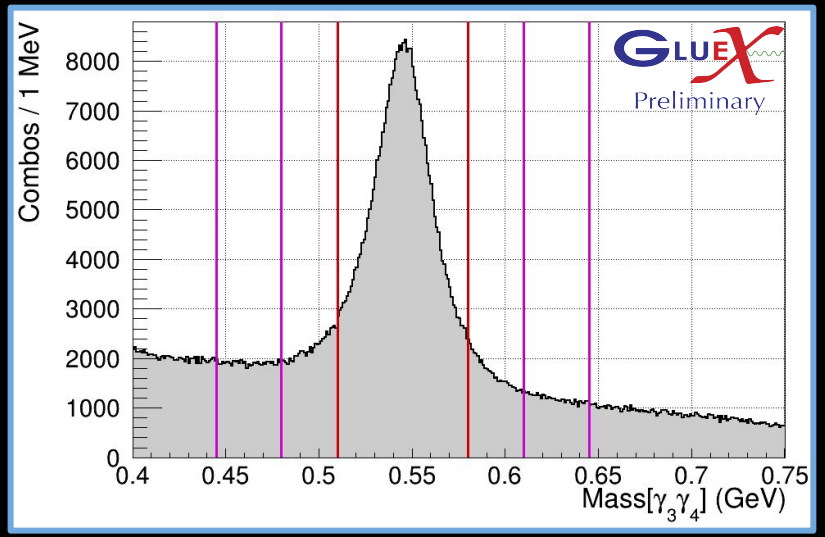
Backup

Background Subtraction: 2D Sidebands

- We performed a 2D sideband subtraction where we add back "not-ω-not-η" background
- The "ω-not-η" and "η-not-ω" backgrounds are seen when plotting the sidebands. They are not obvious in distributions below

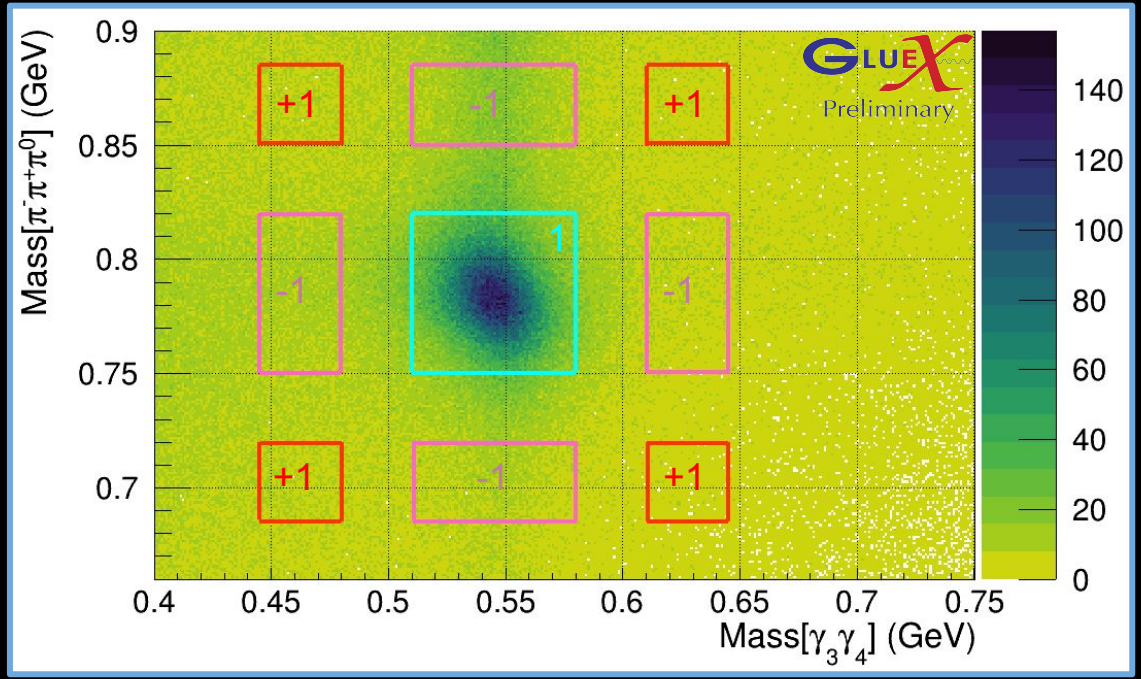
Full GlueX-I





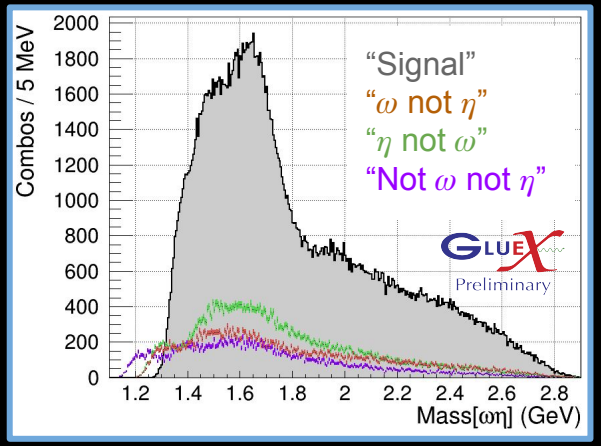
2D Sideband Weighting Scheme

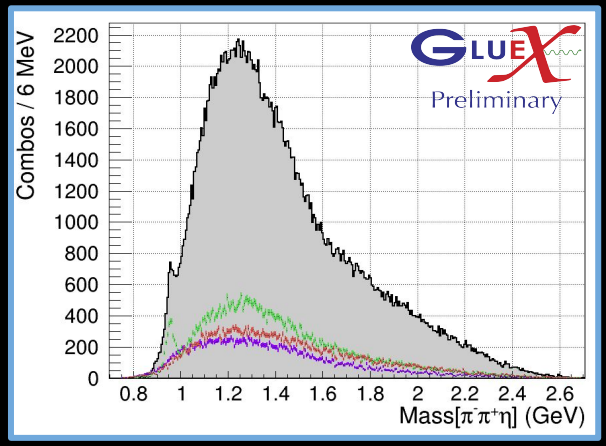
- A 2D sideband subtraction is necessary to avoid over subtraction of events
- The corners add back no-η no-ω background which is double counted in the pink rectangles

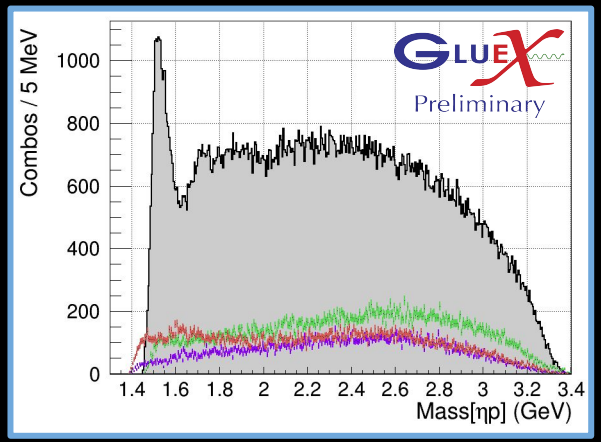


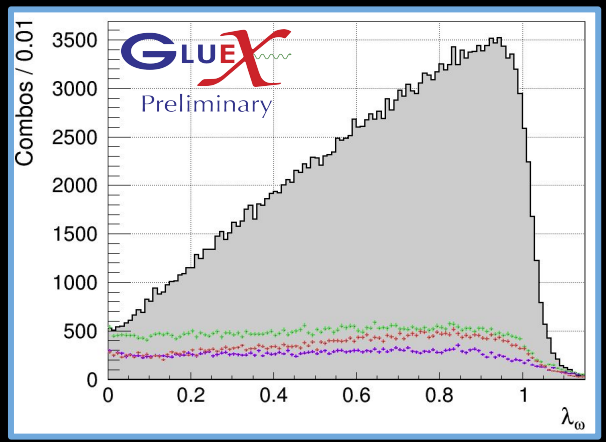
Exploring Sidebands Regions

- λ_ω: Illustrates the importance of adding the "corners" back
- η': clearly visible in the "η-not-ω" sideband
- N(1535): The sidebands don't affect it









Sidebands Subtraction Checks

- λ_ω: background gone
- η': gone
- N(1535): still there
- Threshold effects are seen in M[$\omega\eta$] and M[ηp]. These are avoided when selecting the range for the PWA